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National Defence / Défense nationale

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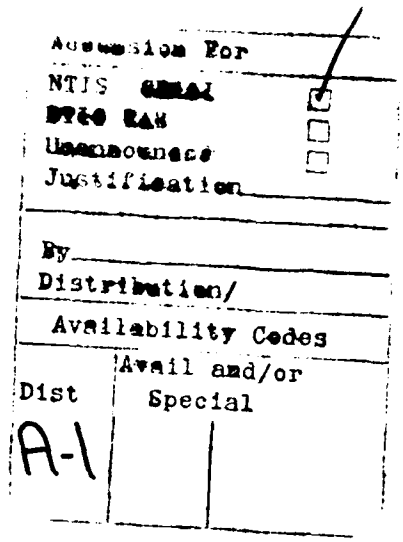
DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 92-8

Canada

March 1992
Ottawa

National Défense
Defence nationale



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PCN
051LC11

March 1992
Ottawa

ABSTRACT

This study was undertaken to document the continued increase in rectal temperature after exercising in the heat. Also, the effects of posture and clothing during recovery, and temperature of the recovery room were examined. Five men exercised at a moderate intensity at 35°C and 50% relative humidity until their rectal temperatures reached 38.5°C. All subjects recovered at a room temperature of 35°C or 22°C, while in a sitting or lying posture. These conditions were evaluated while the subject recovered wearing either a Canadian Forces Chemical Warfare (CW) overgarment or light clothing (combat pants or shorts and a short sleeved shirt). Rectal and skin temperatures were measured each minute during exercise and recovery. After exercise, rectal temperature increased above 38.5°C, however, this increase was slight. Posture and clothing as well as recovery environment affected the magnitude of this afterise. It was concluded that the optimal condition in this experiment that minimized the post-exercise temperature afterise, was recovery at 22°C while sitting without the CW overgarment.

RÉSUMÉ

Cette étude fut entreprise pour documenter l'augmentation continue de la température rectale après exercice dans la chaleur. Egalement, les effets de la posture et des vêtements durant la récupération et la température de la salle de récupération furent examinés. Cinq hommes se sont exercés à une intensité modérée à 35°C et 50% d'humidité relative jusqu'à ce que leurs températures rectales atteignent 38.5°C. Tous les sujets ont récupéré dans une pièce à 35°C ou 22°C, dans une position assise ou couchée. Ces conditions furent évaluées pendant que le sujet récupérait alors qu'il portait soit un pardessus de guerre chimique (CW) des Forces Canadiennes ou de légers vêtements (pantalons de combats ou pantalons courts et une chemise à manches courtes). Les températures rectales et de la peau furent mesurées à chaque minute durant les exercices et la récupération affectaient la magnitude de cette hausse. Il fut conclu que les conditions optimales qui minimisaient la hausse de température d'après exercices, étaient la récupération à 22°C, dans une position assise, sans le pardessus CW.

EXECUTIVE SUMMARY

An initial investigation was done to examine the continued rise in deep body temperature after completion of exercise in the heat. This phenomenon is similar to the continued decrease in deep body temperature that occurs after a person has been removed from a cold environment.

Because of ethical considerations, the limits to which body temperatures (rectal) are allowed to rise or fall during human experimentation are 39.0°C and 35.0°C respectively. Since the continued rise in body temperatures after heat exposure has not been well documented, concern has been raised about the appropriateness of the upper limit of 39.0°C.

The temperature response of five young male, military subjects was examined during recovery after moderate treadmill or stationary bicycle exercise in an environmental chamber controlled at 35°C and 50% relative humidity (RH). All subjects wore a Canadian Forces Chemical Warfare (CW) overgarment while exercising. The subjects recovered inside the environmental chamber (warm) or an adjacent laboratory (22°C, 60% RH) (cool). They recovered, in either a sitting or lying position, wearing a CW overgarment or light clothing (combat pants or shorts and short sleeved shirt). These conditions were selected since the post-exercise temperature response may be dependant upon the temperature of the recovery room, clothing worn, as well as the posture of the subject during recovery.

This preliminary study showed a continued rise of body temperature after exercise in warm environments in most subjects. Under the conditions of this experiment, the rise was usually limited to less than 0.1°C. Posture, as well as recovery environment influenced its magnitude. Despite difficulties associated with comparing bicycle and treadmill exercise, it was concluded that recovery while sitting at 22°C resulted in the least temperature afterise and greatest cooling rates.

INTRODUCTION

During studies involving exercise in hot environments, rectal temperature would continue to rise even after the exercise was stopped (S.D. Livingstone, 1991). If rectal temperature dramatically increases after exercise, then the current exercise termination temperature (typically 38.5°C to 39.0°C), or post-exercise recovery conditions may have to be reconsidered.

It was purpose of this experiment to determine if a post-exercise afterise could be produced, to document it, and to examine the effects of three variables on the afterise. The variables investigated in this experiment during recovery were;

a) the posture of the subject,
b) the environmental temperature, and
c) the effect of wearing a chemical warfare (CW) overgarment.

It was hypothesized that an increasingly upright posture, increased environmental temperature, and increased garment insulation would all act to increase the post-exercise body temperature afterise.

METHODOLOGY

The subjects were five active male military personnel of the Canadian Forces (CF), aged 22 to 27 years old. All subjects participated in each experimental condition. Prior to experimentation, subjects were weighed, and height and body fat skinfolds were measured. These characteristics are given in Table 1. Skinfold thickness was measured at the following sites: subscapularis, pectoralis, sternum, supra iliac, umbilicus and the thigh.

TABLE 1. Anthropometric Characteristics of Test Subjects

Subject no.	Age (years)	Height (cm)	Weight (kg)	Body Fat (%)
1	24	179	90	19.4
2	24	175	93	20.4
3	24	176	95	15.9
4	27	189	80	9.5
5	26	183	83	10.3
Mean	25	180	88	15.1

The experiment was divided into two parts as shown in Table 2. Initially, a second set of experiments was planned to investigate the effects of altered garment insulation on post-exercise afterise. This second set would have been identical to the first part, except for the amount of garments worn during recovery. Unfortunately, equipment failure at the end of the first experiment required the substitution of treadmill exercise with bicycling. As a result, these two parts could not be combined and are reported separately.

Table 2. Summary of Experimental Conditions

	Part 1	Part 2
Equilibrium Period	35°C, sitting, Light clothing + CW Overgarment	35°C, sitting, Light clothing + CW Overgarment
Exercise Type	Treadmill	Bicycle
Exercise Environment	35°C, 50% RH	35°C, 50% RH
Clothing Worn		
Exercise	Light clothing + CW Overgarment	Light clothing + CW Overgarment
Recovery	Light clothing + CW Overgarment	Light clothing
Recovery Conditions	35°C, sitting 35°C, lying 22°C, sitting 22°C, lying	35°C, sitting 35°C, lying 22°C, sitting 22°C, lying

Common to each part was an equilibration period which was completed in an environmental chamber maintained at 35°C and 50% RH throughout the experiment. The equilibration period consisted of the subject sitting quietly in the environmental chamber in light clothing (CF combat pants or shorts and a short sleeved shirt) for one hour. This was done in an attempt to allow the subjects' body temperatures to stabilize and minimize the variability between sessions.

Exercise periods were comprised of two parts. In each part, the subject donned a CW overgarment over light clothing (CF combat pants or shorts and a short sleeved shirt). Subjects wore the same clothing for each session. In Part 1, the subjects walked on a treadmill set at 5 $km \cdot hr^{-1}$ and 2.5% grade. In Part 2 a bicycle ergometer was substituted for the treadmill. An workload equivalent to the treadmill workload in Part 1 was chosen. This was approximately 400 W.

During each experiment, skin temperatures were measured at seven sites; head, arm, hand, foot, shank, thigh, and trunk using thermistors (YSI 44004) attached to the skin with Blenderm surgical tape (3M Co.). Rectal temperature was measured by inserting a rectal thermistor (YSI series 400) approximately 15-20 cm into the rectum as recommended by Sawka and Wenger (1988). Rectal and skin temperatures were collected every minute by an automated data acquisition system (HP 85 computer and HP 3497A Data Acquisition/ Control Unit). Mean skin temperature (T_{sk}) and mean body temperature (T_b) were calculated by a weighted average of skin and rectal (T_r) temperatures according to the equations of Hardy and Dubois (1938) and Burton (1935) respectively:

$$T_{sk} = 0.07T_1 + 0.14T_2 + 0.05T_3 + 0.07T_4 + 0.13T_5 + 0.19T_6 + 0.35T_7$$

$$T_b = 0.67T_r + 0.33T_{sk}$$

where: T_1 = head, T_2 = arm, T_3 = hand, T_4 = foot, T_5 = leg, T_6 = thigh, T_7 = trunk

Heart rate, monitored by a Sport Tester 3000 heart rate monitor, was periodically checked as a safety precaution. Two consecutive heart rates of 180 beats per minute (bpm) or more taken 30 seconds apart were the heart rate criteria for stopping the test.

The subjects exercised until a rectal temperature of 38.5°C was reached. Exercise was then stopped and the subject recovered in one of the four following conditions:

- warm environment (35°C), sitting
- warm environment (35°C), lying
- cool environment (22°C), sitting
- cool environment (22°C), lying

The order of recovery conditions was randomized for each subject.

Recovery out of the environmental chamber occurred in an adjoining laboratory where the ambient conditions were maintained at 22°C and approximately 60% RH. The subject recovered for 30 minutes while skin and rectal temperatures were collected every minute. In Part 1 (treadmill), the subjects recovered while wearing the CW overgarment, while in Part 2 (bicycle) the CW overgarment was removed immediately after exercise and recovery was in light clothing.

A minimum of two days between sessions was allowed to minimize any potential effects due to heat acclimation. Water was given ad libitum throughout the sessions.

Analysis of the data was accomplished by implementing a 2 X 2 X 2 (2 postures X 2 recovery environments X 2 clothing) Analysis of Variance using SYSTAT software as described by Wilkinson (1990).

RESULTS

PART 1 - Treadmill Exercise, Overgarment Recovery

The trends of rectal temperature (T_r), skin temperature (T_{sk}), and body temperature (T_b), averaged over the five subjects, are shown in Figures 1, 2, and 3 respectively. Each of these temperatures tended to be higher when recovering at 35°C (warm) as opposed to recovering at 22°C (cool). When recovering at 22°C, all three temperatures were slightly greater when lying than when sitting. The opposite is true when recovering at 35°C; all temperatures were slightly greater when sitting than when lying.

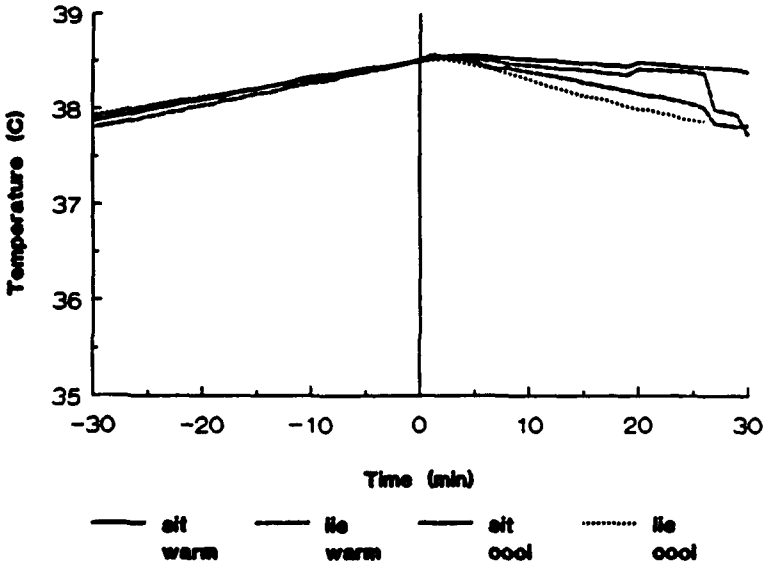

Figure 1. Average rectal temperatures in. each condition (n=5) for Part 1 (treadmill exercise, overgarment). t = 0 represents the end of exercise, and the beginning of recovery

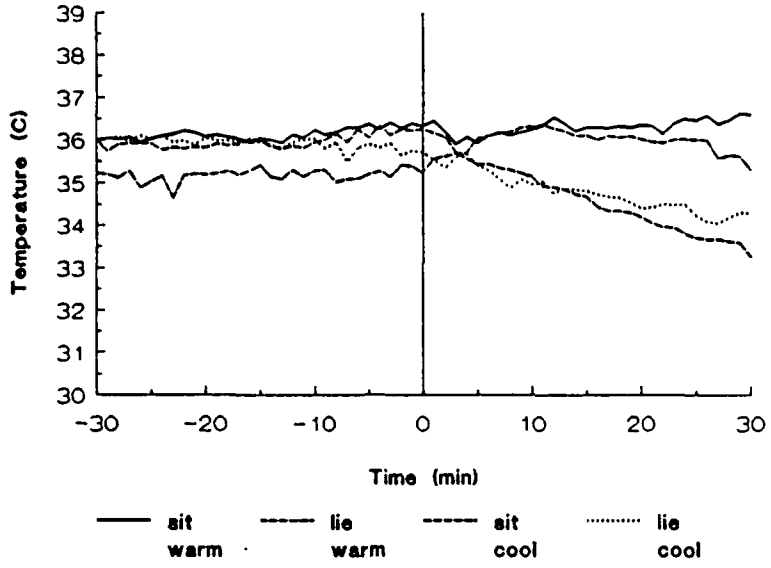

Figure 2. Average **skin** temperatures in each condition (n=5) for Part 1 (treadmill exercise, overgarment). t = 0 represents the end of exercise, and the beginning of recovery.

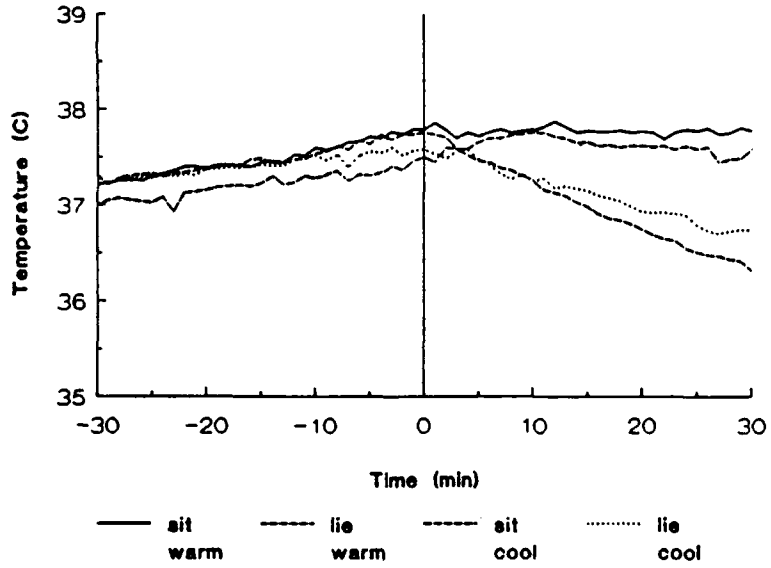

Figure 3. Average **body** temperatures in each condition (n=5) for Part 1 (treadmill exercise, overgarment). t = 0 represents the end of exercise, and the beginning of recovery.

Peak rise in rectal temperature after exercise is given in Table 3. In all instances, with the exception of subject 1 sitting at 22°C, a post-exercise rise in rectal temperature occurred. There was no statistical difference between any of the recovery conditions or postures in the magnitude of this rise. Recovery at 35°C generally resulted in a greater temperature rise than recovery at 22°C. Sitting at 35°C resulted in the greatest mean rise in rectal temperature (0.10°C), while sitting at 22°C resulted in the lowest mean temperature rise (0.04°C).

TABLE 3. Increase of Rectal Temperatures After Exercise for Part 1

Peak T_r Above 38.5°C

Subject	warm/sit	warm/lie	cool/sit	cool/lie
1	0.08	0.03	0.00	0.02
2	0.13	0.11	0.02	0.04
3	0.17	0.07	0.02	0.15
4	0.05	0.08	0.11	0.05
5	0.08	0.04	0.04	0.01
Mean	0.10	0.07	0.04	0.05
SD	0.04	0.03	0.04	0.05

Body fat measurements correlated with afterise across all conditions suggesting that temperature afterise is directly associated with the amount of body fat ($r=.47$, $p<.05$). Greater body fat tended to be associated with an increasing afterise.

PART 2 - Bicycle Exercise, Light Clothing Recovery

The trends of T_r, T_{sk}, and T_b, averaged over the five subjects are shown in Figures 4, 5, and 6 respectively. Each temperature (T_r, T_{sk}, and T_b) tended to be higher when recovering at 35°C (warm) as opposed to recovering at 22°C (cool). With respect to posture, all temperatures were slightly higher when recovering in the lying position rather than sitting at both 22°C and 35°C.

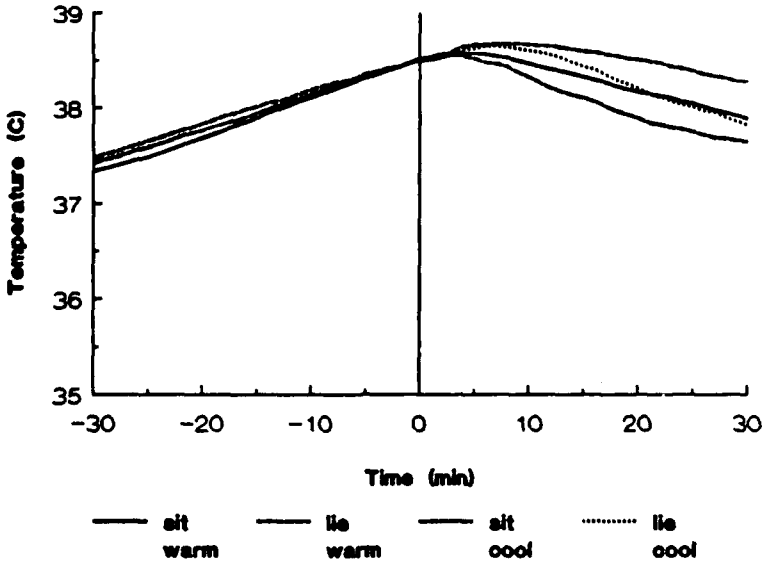

Figure 4. Average **rectal** temperatures for each condition (n=5) in Part 2 (bicycle exercise, light clothing). t = 0 represents the end of exercise, and the beginning of recovery.

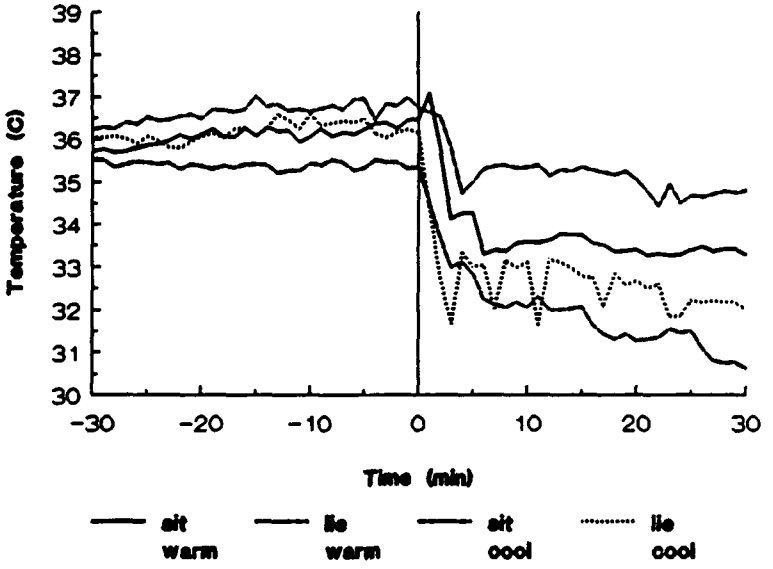

Figure 5. Average **skin** temperatures for each condition (n=5) in Part 2 (bicycle exercise, light clothing). t = 0 represents the end of exercise, and the beginning of recovery.

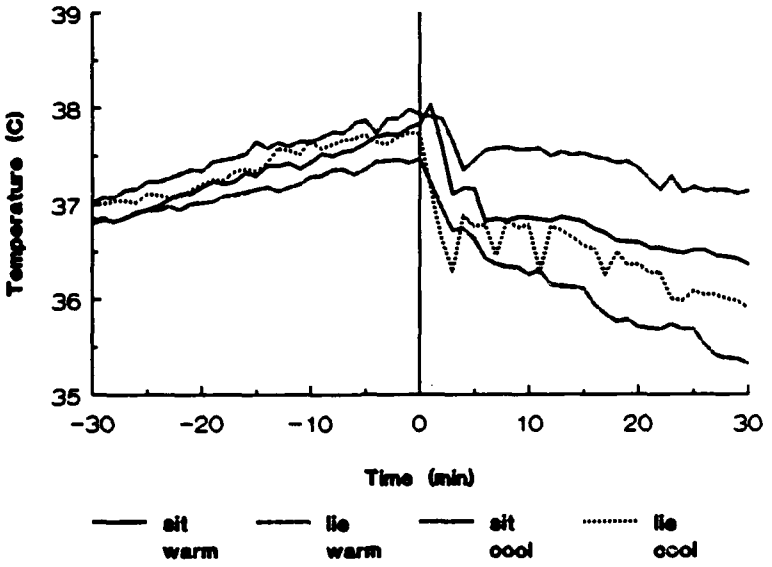

Figure 6. Average body temperatures for each condition (n=5) for Part 2 (bicycle exercise, light clothing). t = 0 represents the end of exercise, and the beginning of recovery.

Table 4 shows the continued rise in rectal temperature after bicycle exercise for each subject and group means in each experimental condition. A continued rise in rectal temperature was noted in all conditions during the first 5 to 10 minutes of recovery. Analysis of variance revealed that posture influenced afterise such that a lying posture resulted in a greater rise than sitting ($p<.05$). Environmental temperature had no effect on the afterise ($p>.05$)

TABLE 4. Increase of Rectal Temperatures After Exercise for Part 2.

Peak T_r Above 38.5°C

Subject	warm/sit	warm/lie	cool/sit	cool/lie
1	0.03	0.19	0.04	0.09
2	0.15	0.36	0.08	0.30
3	0.13	0.13	0.03	0.13
4	0.05	0.24	0.03	0.05
5	0.14	0.15	0.15	0.30
Mean	0.10	0.21	0.07	0.17
SD	0.05	0.08	0.05	0.11

Unlike Part 1, no relationship between body fat content and peak afterise could be determined.

DISCUSSION

Afterdrop is a continued decrease in core temperature during the initial period of rewarming after hypothermia. Current studies (Collins, Easton, & Exton-Smith, 1982; Romet, 1988) conclude that the afterdrop is partly due to the physical process of conductive heat exchange and partly due to cold blood returning from the skin to the core. Afterise may be thought as being analogous to afterdrop in that mechanisms such as conductive and convective heat flow from the tissue and blood may result in an elevated post-exercise rectal temperature.

It is apparent that the occurrence of a post-exercise afterise is a common phenomenon, as demonstrated by its appearance in all conditions of this experiment. On average, it was relatively small with the posture and recovery environment affecting the magnitude of this rise.

Posture affects the distribution of blood in a person by increasing hydrostatic pressure and subsequent pooling of blood in the lower limbs as one progresses from a lying to a sitting and then to a standing position. In Part 2, lying recovery after bicycle exercise resulted in a greater afterise than sitting. This postural effect was not as evident in Part 1 when treadmill exercise was performed. A plausible explanation for this observation may be found in the fact that there are postural differences between bicycle and treadmill exercise. The sitting posture of bicycle exercise is closer to a lying position than walking on a treadmill. As a result, sitting after treadmill exercise results in a greater postural change. This change in posture facilitates the venous drainage of the lower extremities. As a result, a rush of warm blood returning from the previously active muscles permeates the rectal area resulting in a post-exercise afterise. Lying down after treadmill exercise may not result in enough additional posturally induced venous drainage to further affect afterise. Thus, there is little apparent differences between sitting and lying after treadmill exercise. Sitting after bicycle exercise does not result in a postural change, therefore, an afterise due to venous drainage would not be as evident. Differences in afterise between sitting and lying recovery after bicycle exercise would then appear to be exaggerated when compared to treadmill exercise.

It was not surprising that recovery at 22°C resulted in greater cooling than at 35°C, as the greater thermal gradient from the skin to the ambient environment enhances the loss of heat from the body.

The experiment was originally designed to be in two parts to allow comparisons of the effect of garment insulation on rectal temperature afterise during recovery. As mentioned previously, mechanical difficulties necessitated the substitution of bicycle exercise for treadmill exercise in part 2. Despite attempts to select equivalent workloads, it was decided that comparisons between parts 1 and 2 could not be made due to the differences in active muscle groups and posture between treadmill and bicycle exercise. Thus the effect of garment insulation during recovery remained undefined.

CONCLUSIONS AND RECOMMENDATIONS

In the conditions of this experiment, a post-exercise afterise occurred in every subject. The mean afterise was small, averaging between 0.04°C and 0.10°C in Part 1 (treadmill) and 0.07°C and 0.17°C in Part 2 (bicycle).

Both posture and recovery environment affected the magnitude of the afterise. A lying posture and recovery at 35°C tended to result in a greater afterise. The effects of garments worn during recovery could not be determined due to the different types of exercise employed in the two parts. In these experimental conditions, the optimal conditions for cooling and minimizing post-exercise afterise was in a sitting position at 22°C.

Based on the results of this pilot study, it is recommended that further research be initiated to further describe the nature and mechanisms of post-exercise deep body temperature afterise.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. S.D. Livingstone and Mr. R.W. Nolan of the DREO Physiology Group who offered expertise and assistance to this project and to Mrs. Scott who so willingly prepared this manuscript for publication. Without her expertise none of this would have been possible.

The authors would also like to acknowledge the cooperation of the members of the DREO Test Team who acted as test subjects during this evaluation.

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1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.)

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3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)

AFTERISE: Deep Body Temperature Following Exercise (U)

4. AUTHORS (Last name, first name, middle initial)

S. Tuck and A.A. Keefe

5. DATE OF PUBLICATION (month and year of publication of document)	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)	6b. NO. OF REFS (total cited in document)
April 1992	17	6

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Note

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

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9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
051LC11	

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)
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